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RESEARCH ARTICLE

Breeding biology of *Tyrannus melancholicus* (Aves: Tyrannidae) in a restinga reserve of southeastern Brazil

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ABSTRACT. Existing knowledge of the breeding success and life history characteristics of most Neotropical bird species is scarce. Here, we help fill this gap by analyzing aspects of the breeding biology of the Tropical Kingbird *Tyrannus melancholicus* (Vieillot, 1819), which is a good model for this kind of study as it is a common species occurring in various environments, including urban areas, but little is known about its life history. We provide results concerning the breeding period, clutch size, incubation and nestling periods, description of nests, eggs and nestlings, and the plants used for nest sites by this species. Fifty-four nests were monitored over two seasons (2012–2014) in a protected area in southeastern Brazil. Nesting began at the end of the dry season and the beginning of the rainy season. The frequency of active nests varied according to variations in rainfall for each breeding season analyzed. The means and standard deviations of the incubation period (14.2 ± 1.9 days), nestling period (15.1 ± 0.8 days) and clutch size (2.5 ± 0.7 eggs) were similar to values reported for other Neotropical passerines. Twenty-one plant species used as nest trees and for the construction of the nests were identified. The results show that *T. melancholicus* is not highly selective when choosing plant species used for nest construction.

KEY WORDS. Atlantic Forest, breeding season, clutch size, life history, Tropical Kingbird.

INTRODUCTION

The breeding biology and life history characteristics of most Neotropical bird species are poorly known (Martin 1996, Stutchbury and Morton 2008), particularly when it comes to endemic species (Mason 1985, Robinson et al. 2000). Although several studies have investigated the breeding biology of Brazilian Neotropical birds in the Cerrado (Alves and Cavalcanti 1990, Medeiros and Marini 2007, Marini et al. 2009a, b, Duca and Marini 2011), Pantanal (Pinho et al. 2006, Nobrega and Pinho 2010), Atlantic Forest (Alves et al. 2002, Duca and Marini 2004) and grasslands of southern Brazil (Chiarani and Fontana 2015, Repenning and Fontana 2016), the data they generated are limited compared to what is known about birds from temperate regions. The nesting behavior of many tyrannids (New World tyrant flycatchers), for example, is completely unknown, and detailed information on the breeding biology of this group should be expanded (Fitzpatrick 2004).

Tyrannus Lacepede, 1799 includes migratory birds that live in semi-open areas bordering dense vegetation, frequently in cities and often near freshwater bodies (Sigrist 2014). This genus is composed of 13 species, six of which are found in South America (Clements 2007), including the Tropical Kingbird *Tyrannus melancholicus* (Vieillot, 1819), which feeds on fruits and insects (Sick 1997, Höfling and Camargo 2002). Although it is widely distributed in diverse environments, little is known about this species, including its reproductive biology (Legal 2007). In contrast, numerous studies have been conducted on the breeding biology of some of its congeners, such as the Fork-tailed Flycatcher *Tyrannus savana* (Vieillot, 1808) (Teul et al. 2007, Marini et al. 2009a), Western Kingbird *Tyrannus verticalis* (Say, 1823) (Murphy 1988, Bergin 1997) and Eastern Kingbird *Tyrannus tyrannus* (Linnaeus, 1766) (Murphy 2007, Cooper et al. 2009).

The objective of this study was to evaluate the breeding biology of *T. melancholicus* in a restinga area on the southeastern

coast of Brazil and to determine the following nesting attributes: i) mean number of breeding attempts per season; ii) duration of the breeding period; iii) characterization of the nests and eggs; iv) clutch size; v) duration of incubation and nestling periods; vi) offspring development and; vii) identification of the plant species in which nests are placed.

MATERIAL AND METHODS

The study was conducted in the Setiba Environmental Protection Area (Área de Proteção Ambiental de Setiba, hereafter APA-Setiba), which includes the Paulo César Vinha State Park (hereafter PEPCV). The APA-Setiba has an area of 12,960 ha. Inside the APA-Setiba is the PEPCV, which consists of a sand-coastal plain of approximately 1,500 ha, with a length of approximately 12 km and a mean width of 2 km. This park is located in the city of Guarapari, state of Espírito Santo, Brazil, between the coordinates 20°33'–20°38'S and 40°23'–40°26'W (Martins et al. 1999). According to the Köppen classification, the region has a monsoon climate (Am) (Alvares et al. 2013), with hot and rainy summers and dry winters, a mean annual temperature of 23.3 °C, a mean annual rainfall of 1,307 mm, and a mean annual relative humidity of 80 % (Fabris and Cesar 1996). This region has 225 recorded bird species (Venturini et al. 1996), which represent 22.1 % of the total number of bird species described for the Atlantic Forest (MMA 2000).

The PEPCV and APA-Setiba are located in the Atlantic Forest biome, specifically in a restinga ecosystem (sand-coastal plain), where the characteristic vegetation is dominated by non-flooded open shrubland formations composed of herbaceous plants, shrubs and even trees (Pereira 2003). This non-flooded open shrubland formation is characterized by islands of vegetation interspersed with areas of white sand formed by marine quartz, with elevated temperatures and salinity and poor soil (Pereira 2003). The shrubs primarily consist of *Clusia hilariana* Schlechtendal (Clusiaceae) and *Protium icicariba* (DC.) Marchand (Burseraceae) organized into thickets and interthickets. Forest edges are found along with open vegetation formations. The forest formations of the restinga have an upper-canopy strata between 6 and 10 m, a lower-canopy strata between 3 and 4 m, and a few emergent trees reaching 18 to 20 m, giving the trees a mean height of 8.4 m (Pereira 2003, Assis et al. 2004a, b).

The data were collected weekly from August 2012 to March 2014, which included two breeding seasons (2012/2013 and 2013/2014). Birds were captured using mist nets and marked with metal bands provided by the National Center for Bird Research and Conservation/Chico Mendes Institute for Biodiversity Conservation (Centro Nacional de Pesquisa e Conservação de Aves Silvestres/Instituto Chico Mendes de Conservação da Biodiversidade – CEMAVE/ICMBIO, license number 3138/7) and with unique combinations of color-bands. We obtained monthly records of captured and/or recaptured birds, except for August 2012 and June and July 2013. As a cloacal protuberance is a morphological characteristic present only in males (Wolfson 1952, Nakamura 1990) and no captured male with a cloacal protuberance was recorded as also having a brood patch, we used these characteristics to identify the sex of captured individuals: individuals captured during the breeding season were sexed based on the existence or lack of a brood patch and/or cloacal protuberance. The sex of captured birds that had no cloacal protuberance or brood patch was not classified. Estimates of the breeding period were based on the dates in which the studied nests were active, the mating behaviors, and the presence of brood patches and cloacal protuberances in the captured individuals.

The search for nests was actively conducted starting in August of 2012 and extending through February of 2014. The nests encountered were monitored at intervals of 2–3 days and assessed for their contents (empty, eggs, or nestlings). For each nest, the dates of egg laying and hatching and the date that the nestlings left the nest were recorded. The final outcome was also recorded (success, preyed upon, or abandoned). This monitoring provided information for estimating the clutch size, incubation and nestling periods, and nestling development. Data about nestling development were collected via the visual inspection of nestlings, noting skin, bill and feather color and developmental progression.

Only nests that were found before the first egg was laid and where at least one egg survived to hatching were considered for the incubation period estimation. The nestling period was estimated using only successful nests for which the hatching date was known. After the nests became inactive, parts of the nest plants were collected for their identification.

Nest measurements were preferentially performed in the early stages of incubation to avoid the natural deformation resulting from use. The external diameter (mm), internal diameter (mm), height (mm) and depth of the brood chamber (mm) of the nests were measured. Brood chamber depth represents the distance between the center of the chamber to the plane of the top of the nest. The height of the nest above ground was also measured (m). Due to their fragility, the eggs were weighed and measured (length and width) only once between the third and fifth day of the incubation period. The morphological appearance of the eggs (color and shape) and the final clutch size per nest were also recorded.

Monthly rainfall data, collected at the weather station nearest (≈ 45 km) to the study site, were obtained from the Capixaba Institute of Research, Technical Assistance and Rural Extension (Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural – INCAPER) to establish the relationship between rainfall and the number of active nests present at the study site.

A Kolmogorov-Smirnov test was used to assess whether the data were normally distributed. The means are reported with standard deviations. A one-sample goodness-of-fit test (Williams G-test) was performed to test for variations in clutch

size in each season. Simple linear regression was used to analyze relationships between nest plant species and the number of nests, and phytosociological studies were used to obtain the frequency of the occurrence of plant species at the study site (CEPEMAR 2007a, b). All statistical analyses were performed according to Zar (2010), assuming a 5 % significance level. The PAST statistical packages (Hammer et al. 2001) and BioEstat 5.0 (Ayres and Ayres-Jr 2000) were used.

RESULTS

A total of 47 breeding groups were monitored during the study. Fifteen adults were banded from 12 different breeding groups. Among the 47 breeding groups monitored, only two were composed of more than one pair; the other 45 consisted of one breeding pair. A total of 54 nests were monitored (28 nests from the 2012/2013 breeding season and 26 nests from the 2013/2014 breeding season). *Tyrannus melancholicus* breeding pairs performed one to three consecutive breeding attempts within the same breeding season. Only one breeding pair made three attempts, and five breeding pairs made two attempts. The mean number of breeding attempts was 1.15 ± 0.42.

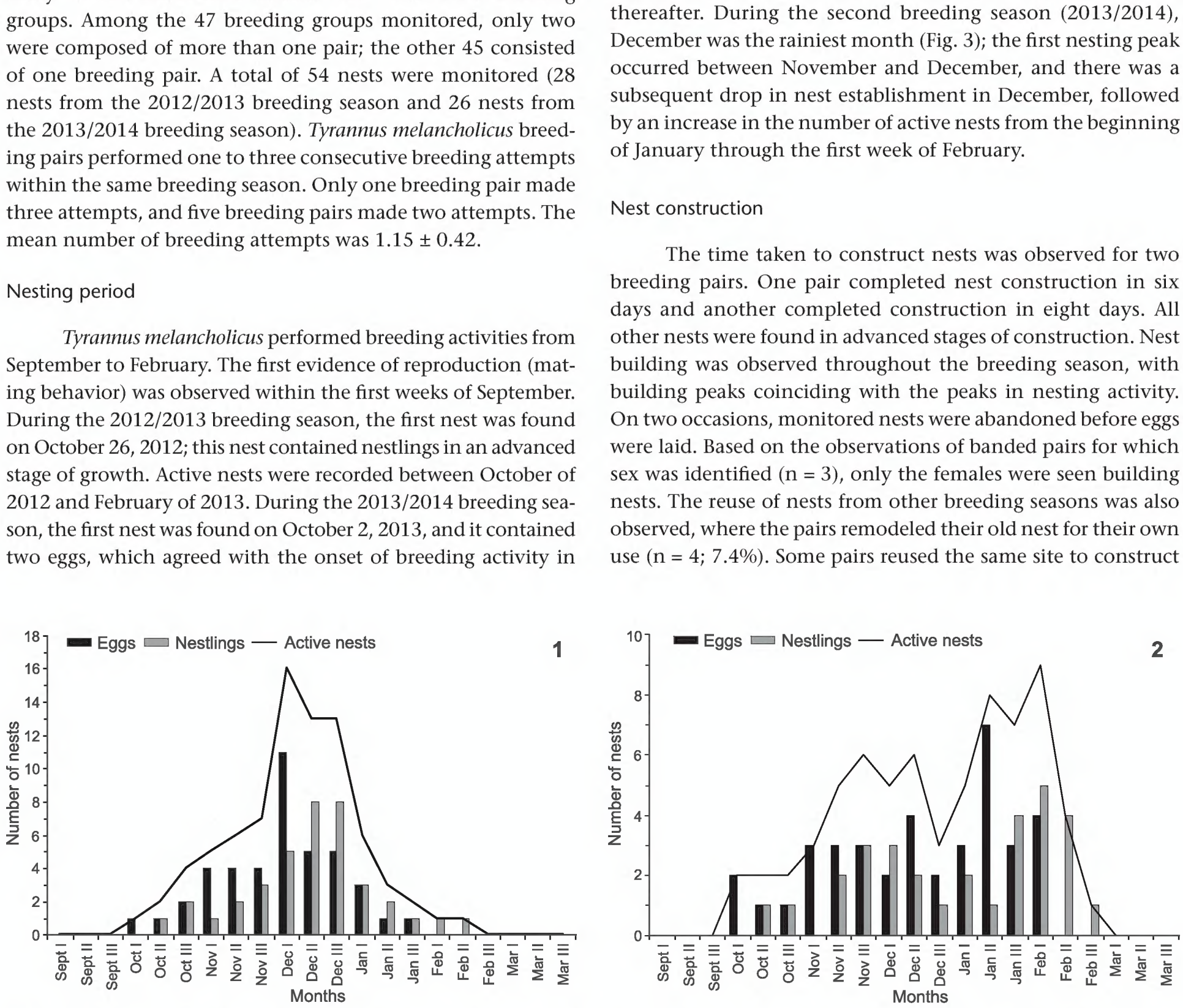
Nesting period

Tyrannus melancholicus performed breeding activities from September to February. The first evidence of reproduction (mating behavior) was observed within the first weeks of September. During the 2012/2013 breeding season, the first nest was found on October 26, 2012; this nest contained nestlings in an advanced stage of growth. Active nests were recorded between October of 2012 and February of 2013. During the 2013/2014 breeding season, the first nest was found on October 2, 2013, and it contained two eggs, which agreed with the onset of breeding activity in September. Active nests were recorded between October of 2013 and February of 2014. During the first year of study, there was a single peak in active nests in December of 2012 (Fig. 1). In the second year of study, the nesting peaks were different from those of the previous year. There were two peaks as follows: a smaller peak between late November and early December and a larger peak between January and early February (Fig. 2). Based on both breeding seasons studied, the nesting period lasted approximately five months (141.5 ± 2.1 days).

In both years, nesting activity began in October and peaked in December in the first year and January/February in the second year. November was the rainiest month in the first breeding season (2012/2013) (Fig. 3), and the nesting peak occurred thereafter. During the second breeding season (2013/2014), December was the rainiest month (Fig. 3); the first nesting peak occurred between November and December, and there was a subsequent drop in nest establishment in December, followed by an increase in the number of active nests from the beginning of January through the first week of February.

Nest construction

The time taken to construct nests was observed for two breeding pairs. One pair completed nest construction in six days and another completed construction in eight days. All other nests were found in advanced stages of construction. Nest building was observed throughout the breeding season, with building peaks coinciding with the peaks in nesting activity. On two occasions, monitored nests were abandoned before eggs were laid. Based on the observations of banded pairs for which sex was identified (n = 3), only the females were seen building nests. The reuse of nests from other breeding seasons was also observed, where the pairs remodeled their old nest for their own use (n = 4; 7.4%). Some pairs reused the same site to construct



Figures 1–2. Seasonal distribution of active *Tyrannus melancholicus* nests and nests with eggs or nestlings at Setiba Environmental Protection Area, Brazil, during the breeding seasons of 2012/2013 (**1**) and 2013/2014 (**2**). Roman letters indicate 10-day periods of each month: I = from day 1 to 10; II = from day 11 to 20; III = from day 21 to 30 (or 31).

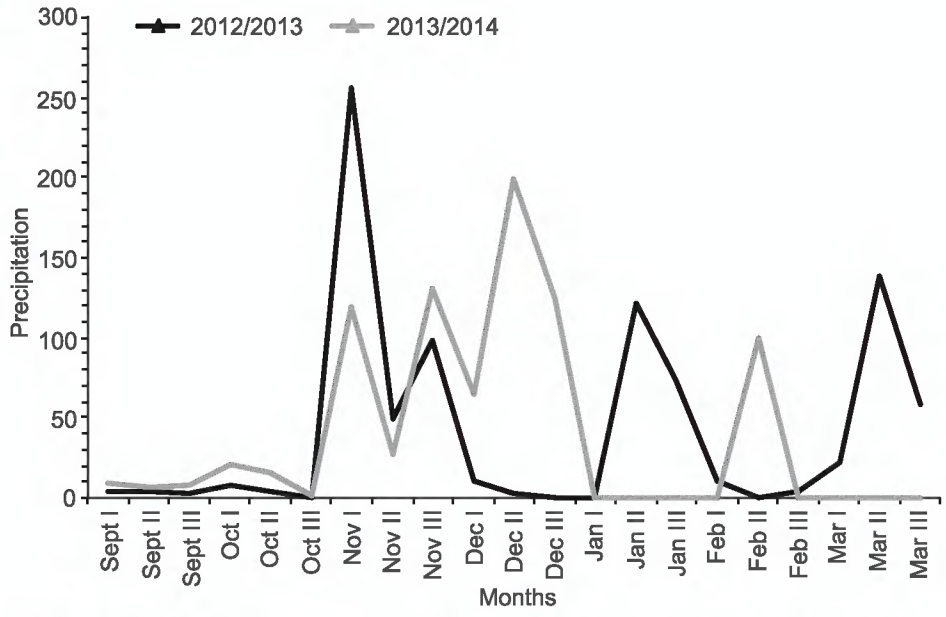


Figure 3. Mean 10-day rainfall in millimeters (mm) from 2012 to 2014 in the Municipality of Guarapari, southeastern Brazil. Roman letters indicate 10-day periods of each month: I = from day 1 to 10; II = from day 11 to 20; III = from day 21 to 30 (or 31). (Source: Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural – INCAPER).

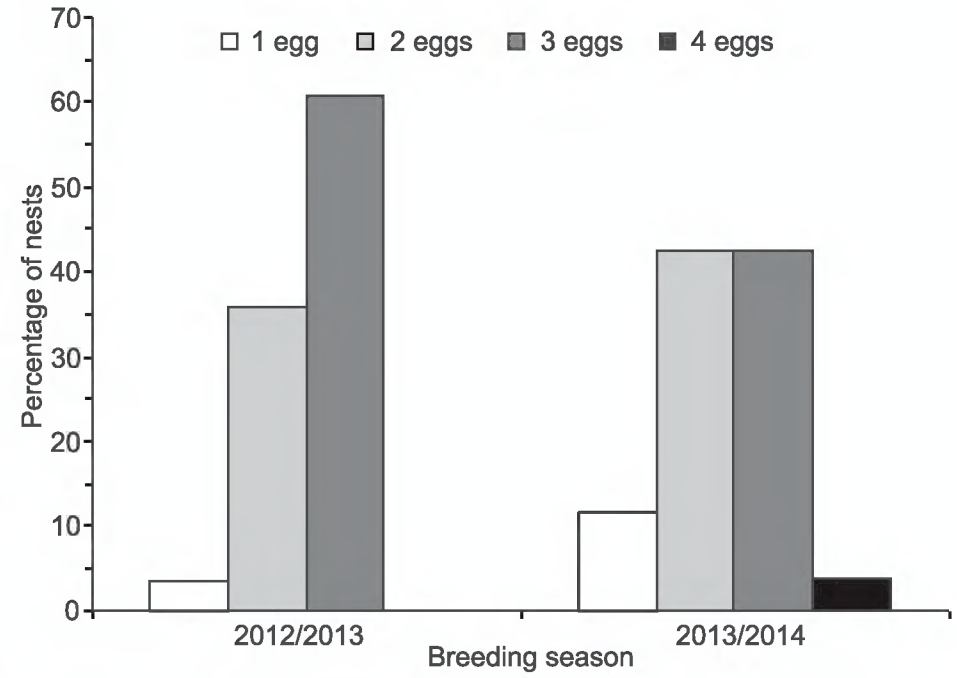


Figure 4. Clutch size of *Tyrannus melancholicus* at Setiba Environmental Protection Area, Brazil, during the breeding seasons of 2012/2013 and 2013/2014.

a new nest (n = 2; 3.7%) after the old nest had disappeared. In addition to reusing nests between breeding seasons, the same nest in the same season was reused for a new breeding attempt (n = 4; 7.4 %). Nest repairs were not observed after eggs were laid.

Characterization of nests and eggs

Nests produced by *T. melancholicus* were always open and cup shaped, with two different types of lining. The external part, which provided protection and support for the nest, had a thicker lining, which included sticks. The internal part of the nest, which held the eggs and nestlings, had a thinner lining composed of small roots, tendrils and frayed fibers from dried leaves. Nests were constructed on emerging branches with little foliage present for protection, allowing almost full exposure to sunlight, and they were always built in the bifurcation of branches. Although the nests were found both close to the ground (0.73 m) and higher up in the trees (3.62 m), nests were, on average, 1.98 ± 0.59 meters (n = 54) from the ground. No nests were found inside bushes or in the tree canopies. The nests measured, on average, 122.35 ± 10.71 mm in external diameter, 77.72 ± 7.42 mm in internal diameter, 73.44 ± 11.08 mm in height and 55.28 ± 5.19 mm in depth (n = 25).

The eggs were ovoid, with colors ranging from white to cream to salmon and with spots and marks ranging between burgundy and brown in color. On average, the eggs were 24.30 ± 1.06 mm in length and 17.23 ± 0.53 mm in width and weighed 2.53 ± 0.19 g (n = 30).

Clutch size

Clutch sizes varied from between one and four eggs, with a mean of 2.5 ± 0.7 eggs (n = 54). Although there was a large number of nests with three eggs in the first year of study, in the second year, there was the same number of nests with two or three eggs, including one nest with four eggs (Fig. 4). No significant differences were found in clutch sizes between the two years evaluated (G = 8.038, df = 27, p = 0.999). The mean clutch size in the first year was 2.6 ± 0.6 (n = 28), and it was 2.4 ± 0.8 (n = 26) in the second year.

Incubation time and feeding of chicks

Egg laying occurred on consecutive days, and nestlings hatched asynchronously since incubation started after the first egg was laid. The mean incubation period was 14.2 ± 1.9 days (n = 10), ranging between 12 and 17 days. The mean nestling period was 15.1 ± 0.8 days (n = 8), ranging between 14 and 16 days.

We observed that only the females incubated the eggs and kept the nestlings warm. The male acted as a sentinel during incubation. The male was always alert and occupied a high perch and alerted the female when there was a potential threat. During the nestling period, both the male and female took turns monitoring the nest and searching for and delivering food to the nestlings. After leaving the nest, fledglings hid in dense groups of bushes, making it impossible to observe them. Despite this, adult behavior indicated that parental care continued for several days after the fledglings left the nest, but it was not possible to define for how long it occurred.

Tyrannus melancholicus showed aggressive, defensive behavior during both the incubation and nestling periods when potential predators approached the nest. Agonistic behaviors were observed by *T. melancholicus* towards the Southern Caracara *Caracara plancus* (Miller, 1777) and Yellow-headed Caracara *Milvago chimachima* (Vieillot, 1816) (both Falconidae), Roadside Hawk *Rupornis magnirostris* (Gmelin, 1788) (Acciptridae), Guira Cuckoo *Guira guira* (Gmelin, 1788) and Smooth-billed Ani *Crotophaga ani* Linnaeus, 1758 (both Cuculidae).

Offspring development

The data on the morphological characteristics and development of offspring were taken from observations of 31 nests that reached the nestling phase. At hatching, the nestlings had their eyes closed. Light beige plumage was observed throughout the body interspersed with areas of bare skin, with a higher concentration of plumage on the head and back. The skin was pink, and the bill was bright yellow. Starting on the fifth day, the skin began to darken and the first signs of the emergence of feather shafts appeared on the back and wings. The eyes began to partially open at this time. On the eighth day, the shafts already exhibited half of the length of the feathers, which began to hide the skin. The eyes were completely open, and the bill was darker. On the thirteenth day, covert feathers had completely emerged, although the rectrices and remiges were not fully developed. On the day that the fledglings left the nest, they had an adult-like appearance but with a yellow gape and shorter rectrices than adults.

Nest plants

Nest plants were identified for 61 *T. melancholicus* nests. The plant species in which nests were most frequently placed was *Kielmeyera albopunctata* Sadddi followed by *Byrsonima sericea* (Table 1). One exotic species, *Acacia mangium* (Fabaceae), was also used. Only one plant species could not be identified. There was no relationship between the frequency of nest plant species at the study site and the number of nests constructed in each plant species ($r^2 = 0.121$, df = 9, p = 0.738) (Table 1).

Table 1. Nest plant species used, number and percentage of *Tyrannus melancholicus* nests per plant species at Setiba Environmental Protection Area, Guarapari, Brazil.

Nest plant species	Number of nests	Percentage of nests (%)
Kielmeyera albopunctata	11	18.0
Byrsonima sericea	9	14.8
Agarista revoluta	6	9.8
Erythroxylum nitidum	6	9.8
Clusia hilariana	4	6.6
Guapira opposita	3	4.9
Manilkara subsericea	3	4.9
Myrciaria floribunda	3	4.9
Humiria balsamanifera	2	3.3
Marlierea neuwiedeana	2	3.3
Neomitranthes obtusa	2	3.3
Acacia mangium	1	1.6
Gomidesia martiana	1	1.6
Guapira pernambucensis	1	1.6
Ilex integerrima	1	1.6
Myrsine umbellata	1	1.6
Ocotea notata	1	1.6
Ouratea cuspidata	1	1.6
Protium icicariba	1	1.6
Salzmania nitida	1	1.6
Unidentified	1	1.6

DISCUSSION

Tyrannus melancholicus attempted successive breeding attempts within the same season, with a maximum of three attempts per season. The behavior of performing multiple breeding attempts in the same season is commonly reported among tyrannids (e.g., Haverschmidt 1971, Skutch 1997, Lopes and Marini 2005, Hoffmann and Rodrigues 2011). In the same restinga area studied here, up to four breeding attempts in one season were observed for the Tropical Mockingbird *Mimus gilvus* (Vieillot, 1807) (Mimidae) (Luiz Carlos de Araújo and Charles Duca 2016, unpublished data). The number of attempts made by some Mimidae species is thought to be influenced by predation and breeding success (Laskey 1962). In a transition area between the Atlantic Forest and the Cerrado, up to three attempts were observed for the Gray-backed Tachuri *Polystictus superciliaris* (Wied, 1831) (Tyrannidae) (Hoffmann and Rodrigues 2011), whereas up to four attempts were observed for the Campo Suiriri *Suiriri affinis* (Vieillot, 1818) and up to five for the Chapada Flycatcher *Suiriri islerorum* (Zimmer, Whittaker & Oren, 2001) in an area of the Cerrado in central Brazil (Lopes and Marini 2005).

New attempts at reproduction within the same season can occur for various reasons, the most common of which is predation pressure (Stutchbury and Morton 2001). The number of breeding attempts can be positively influenced by the overabundance of food (Simons and Martin 1990, Hoi et al. 2004), as well by the presence of helpers (Cockburn 1998, Cafrey 1999). According to Roper (2005), in some situations, only a high number of breeding attempts are able to ensure breeding success for birds in tropical regions, which are known for their high predation pressure. It is possible that some bird species begin their breeding period early to increase the number of attempts in case of failure (Lopes and Marini 2005, Hoffmann and Rodrigues 2011). Moreover, the number of breeding attempts in a breeding period may vary based on experience, with older females performing more breeding attempts than inexperienced females (Roper 2005).

Nesting period

Tyrannus melancholicus had a relatively long nesting period of approximately five months. In the Cerrado of central Brazil, *T. savana* was found to have a breeding period varying from three to four months (Thaís Martins Pimentel unpublished data) and from two to three months (Marini et al. 2009a), which were shorter than the breeding period found in this study. This pattern found for *T. savana* is supported by other studies of tyrannids (Aguilar and Marini 2007, Marini et al. 2009a) and other Passeriformes from the south-central region of Brazil (Pinho et al. 2006,

Rodrigues 2009, Duca and Marini 2011). Moreover, nesting periods equally long as that of *T. melancholicus* were observed in the same south-central region (Marini and Durães 2001) and in southeastern Brazil (Aguilar et al. 1999, Duca and Marini 2004), particularly for *M. gilvus* (six months), which was studied in the same area examined in the present study (Luiz Carlos de Araújo and Charles Duca, unpublished data).

The breeding period of *T. melancholicus* began at the end of the dry season and the beginning of the rainy season in southeastern Brazil, coinciding with the first rains. Mating activities were initiated in September, and the nesting period began in the first week of October. Up to this point, the two breeding seasons considered in this study were similar, but they began to differ at the end of November. In the first breeding season (2012/2013), peak rainfall was observed in November (403.3 mm), followed by a relatively dry December (13.6 mm). After the rainy November, the highest peak in nesting activity occurred over the entire month of December. In the following breeding season (2013/2014), November also had high rainfall (276.1 mm), but peak rainfall did not occur until December (387.6 mm). With the rainfall pattern differing from the previous year, the peak in nesting activity also differed, occurring in the second half of January and the first half of February. This correlation between breeding and rainfall over two breeding seasons suggests that the timing of breeding was driven by the timing of rainfall. A relationship between the nesting season and rainfall was also observed for a species of tanager in the Cerrado of central Brazil, with variation in the start of breeding activities related to changes in mean monthly rainfall (Duca and Marini 2011).

Several other studies have shown a relationship between rainfall and the nesting period of birds in tropical biomes (Aguilar et al. 2000, Mezquida 2002, Auer et al. 2007). This relationship may be linked to the increase in the abundance of food due to rain (Boag and Grant, 1984, Sick 1997). Birds may regulate the timing of their breeding period to coincide with periods of food abundance, which would allow sufficient nutrition for the production of eggs and sufficient food for nestling development (Perrins 1970, Ramo and Busto 1984). According to some studies (Tanaka and Tanaka 1982, Ramo and Busto 1984), an increase in rainfall directly increases insect abundance, thereby favoring insectivorous birds (Oniki and Willis 1983, Jahn et al. 2010). Thus, flexibility in the start of the nesting period allows the birds to address climate unpredictability and, consequently, adjust reproduction to avoid periods with a low abundance of food (Duca and Marini 2011).

Nest construction

Nests were built only by females, which is a characteristic found in other tyrannids such as *S. affinis* and *S. islerorum* (Lopes and Marini 2005), the Lesser Elaenia *Elaenia chiriquensis* Lawrence, 1865 (Tyrannidae) (Medeiros and Marini 2007) and *P. superciliaris* (Hoffmann and Rodrigues 2011). The participation of the male is restricted to a vigilance role while the female prepares the nest. The shape and material used for nest construction were similar to those described for *T. melancholicus* in Santa Catarina (Legal 2007) and for *T. savana* in the Cerrado of central Brazil (Marini et al. 2009a).

The reuse of nests within the breeding season (7.4 %) and the reuse of old nests (7.4 %) and old nest sites between breeding seasons (3.7 %) were observed. Legal (2007) observed the reutilization of nest sites by *T. melancholicus* during two consecutive years. The reuse of nests by species that make open nests is relatively rare (Bergin 1997) but has been recorded for tyrannids with elaborate nests and specialized nest sites, with nests being reused within the same season and between seasons (Aguilar and Marini 2007).

The reuse of nests may confer advantages, such as reduced energy expenditure in the building of nests, and disadvantages, such as the presence of parasites and weak nest structures (Bergin 1997, Friesen et al. 1999). The low availability of nesting sites and the construction of elaborate nests that resist the effects of time may be directly related to the reuse of nesting sites (Aguilar and Marini 2007). Among the advantages of reusing nesting sites is foreknowledge of local predators, food availability, the best nesting sites and competitors (Lindberg and Sedinger 1997, Reed et al. 1998). Fidelity to nesting sites is also a known explanation for this behavior (Bergin 1997, Friesen et al. 1999) and is frequently described for migratory birds with philopatric tendencies, such as *T. melancholicus* (Harvey et al. 1979). Studies also show that breeding success repeated over several years at the same site favors the return of the bird to that site (Harvey et al. 1979, Hepp and Kennamer 1992).

Characterization of nests and eggs

The dimensions listed by Legal (2007) in the description of a *T. melancholicus* nest showed both similarities and differences to the dimensions found in our study. The external and internal lengths were close to the means found in this study (see Legal 2007), whereas the distance from the ground and nest height and depth differed from the means found in this study. The height of the nest from the ground found for the congener *T. savana* in Cerrado (Marini et al. 2009a) was similar to that found for *T. melancholicus* in this study. *Tyrannus melancholicus* lives in different habitats, and it is expected that it can adjust some nest parameters according to habitat characteristics.

The eggs were similar in appearance to those found by Legal (2007) (white with spots ranging from brown to burgundy). However, in the present study, variations in eggshell color were noted: cream and salmon eggs were also found. The mean length and width of the eggs were similar to those found by Legal (2007). Similarities in egg parameters were found when comparing the attributes of *T. melancholicus* eggs with those of its congener *T. savana* (e.g., Mezquida 2002, Di Giacomo 2005, Marini et al. 2009a). In comparison with the eggs of three congeners, *T. tyrannus*, *T. verticalis* and the Scissor-tailed Flycatcher

Tyrannus forficatus (Gmelin, 1789), found in temperate regions, similarities were seen in length and width, and differences were observed in weight (Murphy 1988).

Clutch size

The most common clutch size found in the present study (three eggs) was the same as that of one nest found in southern Brazil (Legal 2007). For the congener *T. savana* in central Brazil, the majority of the nests contained three eggs (Marini et al. 2009a).

The clutch size for *T. melancholicus* was similar to that of *M. gilvus* at the same study site (Luiz Carlos de Araújo and Charles Duca, unpublished data) and was similar to that of several other species from the Brazilian Cerrado (Lopes and Marini 2005, Medeiros and Marini 2007). Small clutch sizes are consistently observed for Neotropical birds, which have smaller clutch sizes compared to birds from temperate regions (Stutchbury and Morton 2008). This difference between temperate and tropical regions can often be observed in the clutch sizes of congeners of *T. melancholicus* in temperate regions, which have mean clutch sizes of 3.4 eggs for *T. tyrannus*, 4.4 for *T. verticalis* and 4.7 for *T. forficatus*, with even larger clutch sizes of up to five and six eggs for *T. verticalis* and *T. forficatus* (Murphy 1988, Jahn et al. 2014).

The main hypotheses explaining the variation in clutch size between these two regions relate to the cost of producing eggs and feeding offspring, as well as variations in temperature, relative humidity, and photoperiods (Ricklefs 2000, Stutchbury and Morton 2008). According to Martin (1987), the ability of parents to feed their offspring can limit the clutch size because larger clutches are costlier to feed. The high predation rate in Neotropical regions may also favor smaller clutch sizes because adults invest in smaller numbers of eggs and larger numbers of breeding attempts to ensure breeding success (Slagsvold 1982).

Incubation and nestling periods

The mean incubation period for *T. melancholicus* (14.2 days) was shorter than that reported for one nest of the same species monitored in southern Brazil (17 days; Legal 2007). For the congener *T. savana*, the incubation period has been reported to vary from 13.6 (Marini et al. 2009a) to 16 days (Thaís Martins Pimentel, unpublished data). Variations in the incubation period may occur depending on environmental conditions and food availability (Murphy 1986, Rotenberry and Wiens 1989).

In forest environments in the Atlantic Forest, the length of the incubation period for *T. melancholicus* was longer than that of the Black-cheeked Gnateater *Conopophaga melanops* (Vieillot, 1818) (Conopophagidae) (12 days) (Alves et al. 2002) and shorter than that of the Red-rumped Cacique *Cacicus haemorrhous* (Linnaeus, 1766) (Icteridae) (18.2) (Duca and Marini 2004). The incubation period of the studied species was similar to that of *M. gilvus* (14 days) in a restinga within the same area were *T. melancholicus* was investigated for the present study (Luiza Carlos de Araújo and Charles Duca, unpublished data). In studies on tyrannids in the Cerrado, similar incubation periods were reported for *S. affinis* and *S. islerorum* (15.2 days; Lopes and Marini 2005) and the Plain-crested Elaenia *Elaenia cristata* (Pelzeln, 1868) (Tyrannidae) (15.2 days; Marini et al. 2009b), but periods were longer for *P. superciliaris* (17.7 days; Hoffmann and Rodrigues 2011). According to Sick (1997), the mean incubation period of most passerine species in the Atlantic Forest is approximately 15 days, and the present study corroborates this trend.

The mean nestling period of *T. melancholicus* (15.1 days) was shorter than the mean time reported by Legal (2007) (18 days) for this species in southern Brazil but was similar to that of other Neotropical tyrannids with open nests (e.g., Medeiros and Marini 2007, Marini et al. 2009a, b, Mezquida 2002, Hoffmann and Rodrigues 2011). The nestling period in this study was shorter than that reported for other Passeriformes, such as *S. affinis* (18.9 days), *S. islerorum* (18.3 days) (Lopes and Marini 2005), *C. melanops* (18 days) (Alves et al. 2002) and *C. haemorrhous* (23.4 days) (Duca and Marini 2004). Shorter incubation and nestling periods may be desirable to reduce the time of exposure to predators (Martin 1987), but early abandonment of the nest can put the fledglings at risk and compromise the development of flight ability and, consequently, the ability to escape from predators (Marini et al. 2009a).

Nest plants

The species of plants in which *T. melancholicus* placed nests suggest that those plant species may be used more often than plant species that are more readily available at the study site. Parameters can be considered selective when applied out of proportion to their level of availability in the habitat, thus showing a process of selection by the animal (Johnson 1980). Indeed, such selection may occur because some birds have a close relationship with the plant species in which they nest (Petersen and Best 1985). Additionally, there is evidence that birds are able to identify nesting sites that reduce the risk of predation due to the difficulty of accessing the site or the amount of vegetation cover above the nests (Stauffer and Best 1986, Martin and Roper 1988).

Tyrannus melancholicus did not appear to be particular about the plant species in which it builds its nest; nests were found in 21 different plant species, most of which were common in the study area. However, the results show that two plant species together accounted for over 30 % of the nest sites [*Kielmeyera albopunctata* (18.0 %) and *Byrsonima sericea* (14.8 %)]. In a vegetation structure survey conducted in the same study area (CEPEMAR 2007b), a relative frequency of occurrence of 4.0 % was found for *K. albopunctata* and of 1.5 % for *B. sericea*, which were seventh and twenty-first in frequency of occurrence, respectively. In this same study, the species most frequently found were *Clusia hilariana* (6.1 %), *Protium icicariba* (4.7 %), *Guapira pernambucensis* (Casar.) Lundell (Nyctaginaceae) (4.7 %) and *Ocotea notata* (Nees and Mart.) (Lauraceae) (4.7 %).

All of these species were used as nest plants by *T. melancholicus*, albeit with a low frequency (6.6 % for *C. hilariana* and 1.6 % for each of the others).

In a study conducted at the same study site, it was found a similar pattern for *M. gilvus*, with the use of 30 plants species for nesting, which were also the most common plants in the area (Rodrigo Morais Pessoa and Charles Duca, unpublished data). However, the plant species containing the highest number of *M. gilvus* nests (15.7 %) was *P. icicariba*. The use of the more abundant plant species (e.g., *K. albopunctata* and *C. hilariana*) in the study area as nest sites is supported by the hypothesis known as the "potential-prey hypothesis" (Martin 1993). This hypothesis suggests that nests located in shrub species that are abundant in the area are safer from predation due to the increased availability of potential sites for nest construction. Thus, there is a reduction in the efficiency of predators in locating nests, and the predation pressure is consequently lessened.

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